PROGRAM HISTORY, *CYCLONE* (PC-1) CLASS

Hydromechanics Directorate (50) Involvement in Design Program

Fig 1. *Shamal* (PC-13) Patrol Coastal of the PC-1 *Cyclone* Class

The Patrol Coastal PC-1 *Cyclone* Class, is the newest generation of Navy four screw high speed crafts designed primarily for coastal patrol and interdiction, with a secondary mission of supporting Special Operations Forces. The *Shamal*, PC-13, (Fig 1) is the thirteenth ship of the PC-1 *Cyclone* Class (Fig 2).

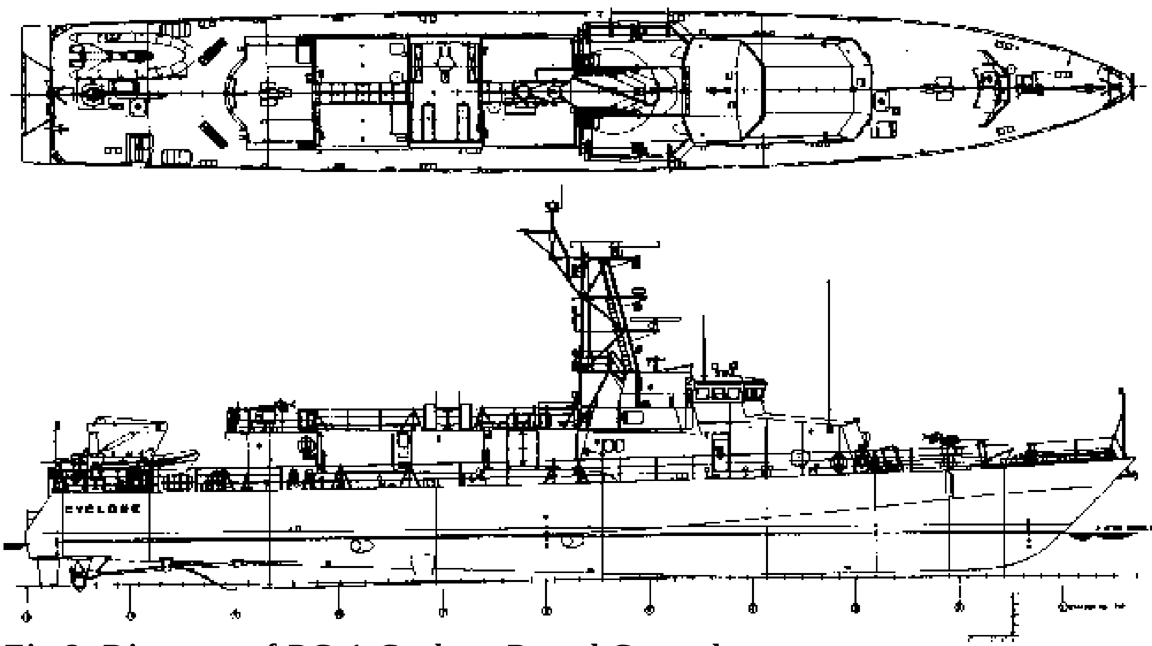

Fig 2. Diagram of PC-1 *Cyclone* Patrol Coastal

The accomplishments of the PC-1 *Cyclone* research and development design program conducted at the David Taylor Model Basin, Naval Surface Warfare Center, Carderock Division (NSWCCD),, which included the design of a new 6-bladed propeller an a stern flap, were as follows:

- Reduced propulsion generated onboard radiated noise and vibration levels
- Eliminated the cavitation erosion damage tendencies to the propeller's blades
- Attained ship's performance requirements at an increased displacement

Backgrund: The set of (fleet) propellers presently fitted to the PC-1 *Cyclone* Class were designed by Vosper Thornycroft Limited (VT), United Kingdom, and were built by both Brunton's Propeller, Sudsbury, England, and Volda Bamford, Ltd., Stockport, England. This fleet propeller design was tested and determined to be unacceptable because it failed to propel the ship to 35 knots (at half load displacement) and did not allow the ship to develop the contractual full power. The fleet propeller blades have also exhibited cavitation erosion damage, and on-board noise levels above the specification requirements.

The US Navy conducted a research and development design program at David Taylor Model Basin, Naval Surface Warfare Center, Carderock Division (NSWCCD), with the preliminary goal of reducing the propulsion generated onboard radiated noise levels in order to improve habitability. Secondary goals were to enable the PC class to meet its performance requirements at an increased displacement, and to eliminate the cavitation erosion damage tendencies to the propeller's blades. This work was authorized through the Combatant Craft Engineering Branch (Code 23) of the Ship Directorate located in Norfolk, Virginia (NSWCCD DET NORFOLK), and coordinated by Carl Casamassina. A detailed history of the PC-1 program is presented by Cusanelli and Jessup, [Ref. 1], and excerpts of that paper are presented herein:

The first model test series included resistance, powering, and propeller disk wake survey experiments. The experiments were conducted on 25 ft (7.6 m) long Model 5497 (Fig 3), with propulsion-sized 7.5 inch (17.8 cm) diameter model scale interpretations of the PC-1 Class fleet propellers.

Fig 3. PC-1 Class Model 5497

The experiments were performed at DTMB, by the Resistance and Powering Department, Code 5200, and provided ship powering and wake data necessary to facilitate the propeller design effort of the Propulsor Technology Department, Code 5400. Dominic Cusanelli was the project engineer in charge of the model experimentation. Stuart Jessup was the engineer in charge of the PC-1 propeller design.

The resistance and powering experiments determined resistance of the fully appended hull, provided predictions of propeller-hull interaction coefficients and efficiencies, and achievable speed and required power. The four screw, high speed - high power output for Model 5497 necessitated a complex test set-up in order to insure that enough model motor power would be available to conduct experimentation through the PC-1 full delivered power range (Fig 4). All four propeller shafts were independently driven by electric motors with individual motor controllers. All four motors were electronically linked with an adjustable feed-back control system which provided equivalent propeller RPMs.

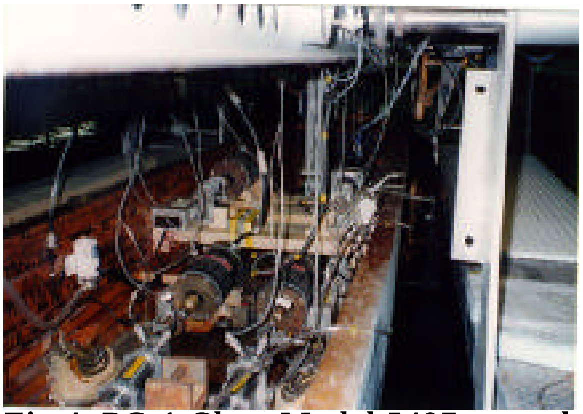

Fig 4. PC-1 Class Model 5497 propulsion test installation

The propeller disk wake surveys measured the three dimensional flow characteristics in way of the inboard and outboard propeller planes, using five-holed hemispherical head pitot tubes (Fig 5).

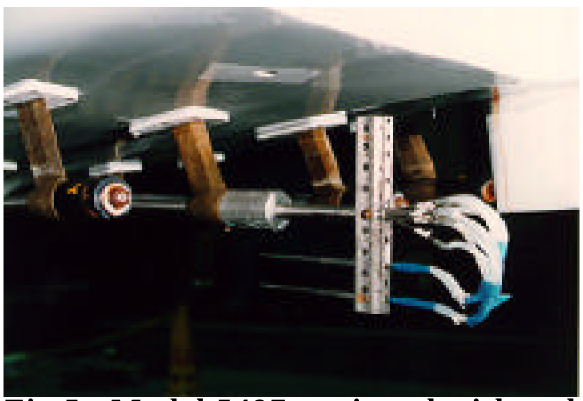

Fig 5. Model 5497 equipped with wake survey rake and pitot tubes

While the propeller design effort was underway, additional experiments on Model 5497 were conducted. Resistance experiments were conducted, the purpose of which was to determine the effect of the engine exhaust ports on PC-1 powering, and to determine the optimum angle of attack for the set of roll stabilization fins. Additional experiments evaluated the PC-1 with the installation of different stern flap designs. The stern flaps were tested at various angles, in order to determine the configuration which would yield the optimum powering characteristics (Fig 6).

Fig 6. Model 5497 stern flap

An initial 4-bladed propeller (propeller 5217, 16 inch diameter) was designed by Jessup (5400). Open water, cavitation (Fig 7), erosion, and acoustic experiments were conducted, and compared to the original PC fleet propeller. Results of these experiments indicated increased cavitation-free speeds, lower acoustic spectra levels, and no propeller blade erosion tendencies. However, propulsion estimates indicated an unacceptable reduction in the maximum ship speed of 1 knot.

Fig 7. Initial 4-bladed propeller 5217, cavitation test

Two 6-bladed 16 inch diameter propellers of the second propeller design by Jessup (5400), were manufactured (propellers 5237 and 5246). Results of model experiments in cavitation tunnel (Fig 8) indicated increased cavitation-free speeds, lower acoustic spectra levels, and no propeller blade erosion tendencies. The geometry of propeller 5246 was found to be more representative of the propeller designer's specifications, therefore, the open water performance of this model was utilized for propulsion predictions which justified the manufacture of propulsion-sized propellers for testing on Model 5497.

Fig 8. Design 6-bladed propeller 5237, cavitation test

The subsequent Model 5497 powering experiments by Cusanelli (5200) provided predictions of achievable speed and required power, matched powering characteristics of the propeller design with the engine operational envelopes, and powering improvements due to the stern flap installation (Fig 9).

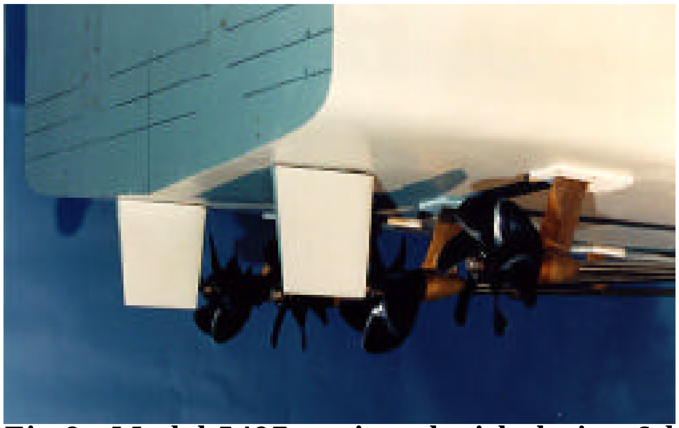

Fig 9. Model 5497 equipped with design 6-bladed propellers

The new propeller design did allow for the development of full engine horsepower potential. However, in order to allow for a greater potential propeller RPM margin, the propeller pitch distribution was modified by the Jessup (5400). The resultant was the PC-1 final US Navy 6-bladed design propeller characterized by 16 in (40.6 cm) diameter model scale propeller 5275. Propulsion predictions were made and this propeller design was then selected for the full scale manufacture.

PC-1 final US Navy 6-bladed design propellers were installed on PC-13 Shamal in August, 1995, (Fig 10); and full scale propulsion, acoustic, and vibration trials were conducted by the Combatant Craft Engineering Branch (Code 23).

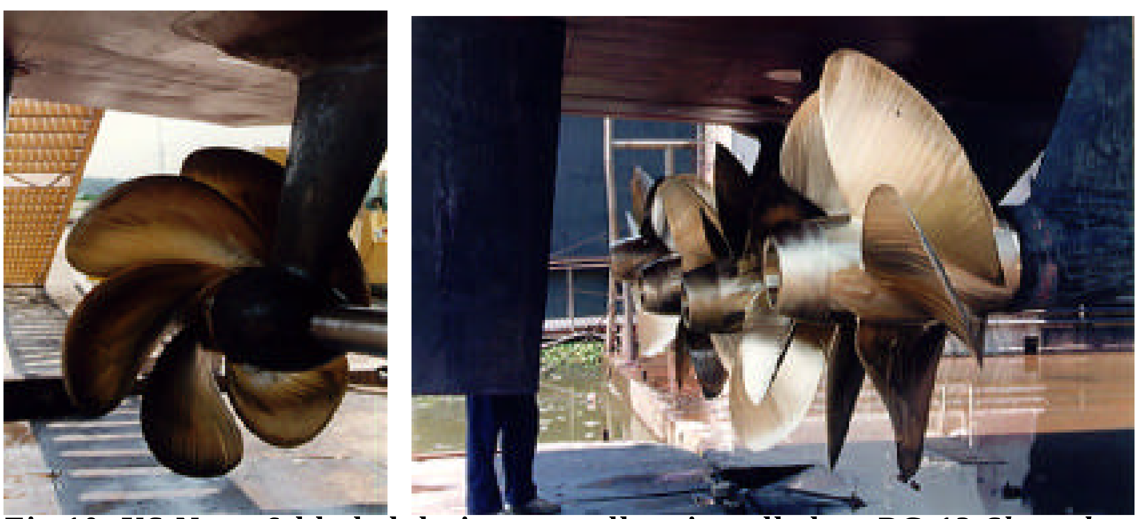

Fig 10. US Navy 6-bladed design propellers installed on PC-13 *Shamal*

The scope of testing also included full scale viewing of the propeller cavitation characteristics underway. This was accomplished with the installation on the hull of two plexi-glass (Lexan) view-ports, placed directly above the propeller plane.

Fig 11. Cavitation viewing on PC-13 *Shamal,* design 6-bladed propeller

The PC-13 *Shamal* was also fitted with the stern flap designed by Cusanelli (5200), and full scale testing was conducted concurrent with testing of the US Navy 6-bladed design propellers (Fig 12). The stern flap provided for a decrease in delivered power throughout the entire speed range, and an increase in maximum attainable ship speed, Cusanelli [Ref. 2].

Fig 12. PC-13 *Shamal,* equipped with stern flap and design 6-bladed propellers

<u>REFERENCES</u>

[1] Cusanelli, D.S. and S.D. Jessup, "Patrol Coastal (PC 1) CYCLONE Class Hydrodynamic Design Improvement Program", MACC'99 Multi Agency Craft Conference, Norfolk, VA (June 1999)

[2] Cusanelli, D.S., "Stern Flap Powering Performance on the PC 1 Class Patrol Coastal, Full Scale Trials and Model Experiments", PATROL '96 Conference Proceedings, New Orleans, LA, (Dec. 1996)

For additional information on the PC-1 *Cyclone* design program contact:

Carl Casamassina, NSWCCD Code 23
Voice: (757) 686-7346,, eMail: CasamassinaCM@nswccd.navy.mil
Dominic S. Cusanelli, NSWCCD Code 5200
Voice: (301) 227-7008, eMail: CusanelliDS@nswccd.navy.mil
Stuart Jessup, NSWCCD Code 5400
Voice: (301) 227-5080, eMail: JessupSD@nswccd.navy.mil